

EFFECTS OF PUNISHMENT INTENSITY DURING VARIABLE-INTERVAL REINFORCEMENT

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When an aversive stimulus, such as electric shock or noise, is explicitly arranged to follow a response, the procedure can be described as punishment. In studying the punishment process as defined above, three major types of procedure have been used extensively. The first of these procedures (Muenzinger, 1934) distinguishes between two classes of response such as correct vs. incorrect and left vs. right. The punishment is typically delivered following one of these responses, but not the other, and the relative frequency is compared. No attempt is usually made in this type of study to determine changes in the absolute strength of either response.

A second type of procedure used in studying punishment does measure the absolute strength of a response, but limits the punishment to the period of experimental extinction (Estes, 1944). Since the extinction process in itself produces a rapid reduction of responding, any reduction due to the punishment can be determined for only short periods of time. Long-term effects of punishment cannot be studied with this method. Of more serious consequence is the possibility, and likelihood, that this simultaneous use of punishment and extinction will give rise to discriminative properties of the punishment. This would be expected to occur inasmuch as the punishment is present only during extinction and not during reinforcement.

The third method of studying punishment involves the simultaneous use of punishment and reinforcement (Skinner, 1938; Dinsmoor, 1952). A substantial level of responding may be established with a food reinforcement, and the punishment is added while this food reinforcement is still maintained. The level of responding during the punishment procedure can then be compared with that in the absence of punishment. Long-term studies are thereby possible in which relative, as well as absolute, measures of responding can be obtained without allowing the punishment to assume discriminative properties with respect to the underlying food reinforcement. Various schedules of food reinforcement may be used to maintain the selected response. In a previous study (Azrin, 1959b), a fixed-ratio schedule of reinforcement was used; and it was found that once responding began, the initial onset, or increase, in punishment produced a large degree of suppression with subsequent recovery in time. The present study is an attempt to study these progressive changes in the effects of punishment. In order to eliminate the cyclic changes in behavior associated with fixed-ratio reinforcement, a variable-interval schedule was used, since this schedule produces a fairly uniform rate of responding.

METHODS AND APPARATUS

The subjects were six male White Carnaux pigeons, each of which was maintained at about 80% of its free-feeding weight.

The experimental chamber measured 16 by 16 by 16 inches. These dimensions provided ample space for the gross movements which were often produced by punishment. The re-

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sponse key was an illuminated plastic disc, 1 inch in diameter, and required a force of 7 grams for closure by the pecking response. This key was located 11 inches above the grid to prevent the wing movements produced by the punishment from activating the response key. The punishment consisted of a brief electric shock of alternating current at 60 cycles per second, which was delivered for a duration of 100 ± 5 milliseconds, except for two subjects which received durations of 30 ± 4 milliseconds. The brevity of the shock duration made it virtually impossible for successive responses to produce overlapping shock impulses. Similarly, this brief duration of shock eliminates the possibility of adventitiously reinforcing behavior which coincides with the termination of shock. The electric shock was delivered through two electrodes, one implanted on either side of the pigeon according to the procedure described elsewhere (Azrin, 1959a). Measurement of the electrical resistance of each subject was taken immediately before and after each experimental session with an ohmmeter having an input of approximately 50 millivolts A. C. The resistance varied between 700 and 1200 ohms among birds; the average deviation was less than 50 ohms for any given bird. No systematic change in resistance was found between or during the sessions with punishment. To determine whether continued presentations of shock would produce changes in resistance, prior tests were made in which shock was delivered without interruption for several minutes. No change in resistance was found as a function of exposure time. These results agree with those obtained by Campbell and Teghtsoonian (1958) with electrified grids. Measurement of the shock intensity will be specified in terms of the input voltage with a 10,000-ohm resistor in series with the subject at all times. An input of 100 volts through this 10,000-ohm resistor in this study produced a measured voltage drop of about 5 volts across the bird, with a measured current flow of about 10 milliamperes. The grid floor was electrically insulated to prevent current flow through the feet. A swivel attached to the wires leading from the subject's harness permitted complete freedom of movement about the experimental chamber. The harness arrangement was worn by the subject at all times, and the input jack was plugged into the harness during all experimental sessions including those without punishment. No replacement or repair of the electrodes was found necessary after the initial implantation. Autopsy of one animal revealed that the electrodes had grown firmly in place, with no apparent irritation of the surrounding tissue.

Prior to the delivery of punishment, each subject had been exposed to a minimum of 50 hours of variable-interval food reinforcement. The mean frequency of food reinforcement was 1 minute for three subjects and 6 minutes for the other three subjects. This food reinforcement consisted of a 3-second exposure to a grain mixture. The daily experimental sessions were usually 1 hour, except as specifically indicated otherwise. Exposure to each punishment intensity was continued until the number of responses between sessions and the pattern of responding within each session appeared stable for at least 10 sessions at a given intensity. The sequence of the punishment intensities was mixed and differed for each subject. Occasionally, several sessions with no punishment were introduced in order to observe any recovery of responding.

RESULTS AND DISCUSSION

Initial Introduction of Mild Punishment

When punishment was initially introduced, the punished responses were found to decrease in frequency; but the continuation of this initial reduction of responding depended critically upon the intensity of the punishment. In Fig. 1 the typical behavioral changes pro-

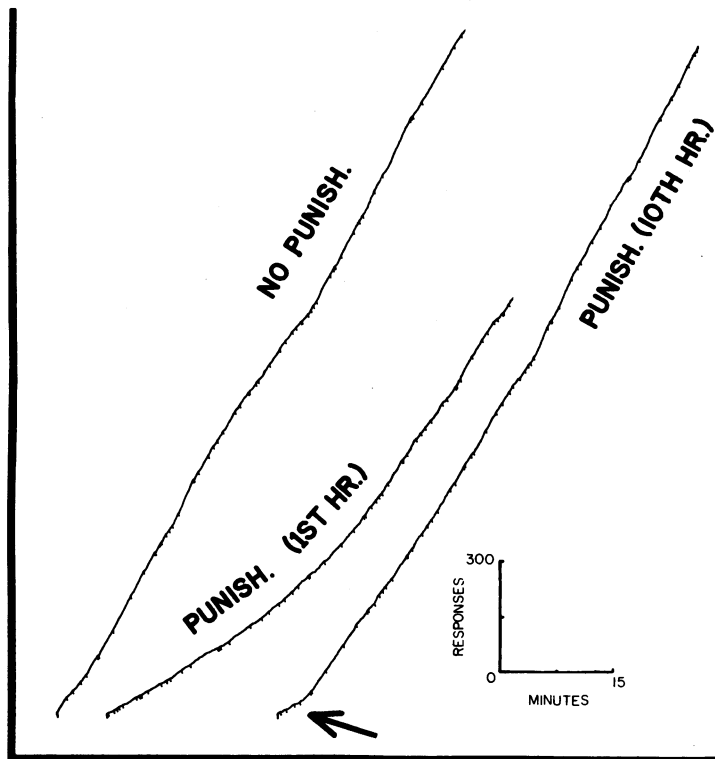


Figure 1. Complete recovery of responding during maintained mild punishment. Each curve is the cumulative record of the responses during a 1-hour daily session. A 1-minute, variable-interval schedule of food reinforcement is present at all times. The small oblique lines on the record indicate the delivery of the reinforcement. The arrow indicates the suppression typically found at the start of each punishment period. The punishment is being delivered following each response during the punishment sessions.

duced by mild punishment are shown for one subject. The left curve is the cumulative record of the responses for the 1-hour session immediately prior to punishment during which time the responding can be seen to be fairly uniform. The middle curve constitutes the response record for the following day, that being the first session under punishment. During this session, every response was followed immediately by an electric shock through implanted electrodes at a shock intensity of 30 volts (in series with the 10,000-ohm resistor, of course) and a duration of 30 milliseconds. The effect of the punishment can be seen to be immediate; responding decreased from its unpunished rate of 40 responses per minute to a rate of less than 15 responses per minute. A gradual acceleration of responding occurred throughout the hour of punishment such that the level of responding had doubled by the end of the hour. On succeeding sessions under punishment, this recovery process continued until there was virtually complete recovery by the 10th hour (right-hand curve). The same intensity of punishment was still following every response during this 10th hour, but the total number of responses for the session is now the same with punishment as it had been without punishment. One distinctive effect of this mild punishment still persists, however; there is a brief reduction of responding at the beginning of the session (arrow). This initial suppression at the beginning of each session has proved to be one of the more persistent ef-

fects of punishment. Even when the total number of responses per session is relatively unaffected by the use of mild punishment, the suppression during the first few minutes often continued. This initial suppression is in contrast with the typically high rate at which responding is seen to occur at the start of a session without punishment. (See the left curve.)

A second characteristic of the responding under punishment is the orderliness of the behavior. No great increase in variability is produced by the punishment in spite of the reduction of the responses. Even the large reduction of responding at the initial introduction of punishment fails to produce any significant increase in variability.

The results presented above have been replicated with all six subjects used, and have also been repeated with the same subject. Complete recovery from the effects of punishment has been found whenever the punishment intensity was less than 20 volts (approximately 1.5 milliamperes) at a duration of 100 milliseconds, or less than 40 volts (approximately 4 milliamperes) at a duration of 30 milliseconds. Although designated as a "mild" intensity in the present study, these intensities are comparable in terms of current flow to the more severe intensities typically used in previous studies of punishment.

Introduction of Moderate Punishment

At punishment intensities greater than 30 volts, recovery from the initial effects of punishment was usually not complete. An example of this is shown in Fig. 2, the top of which presents a typical session of the unpunished responses for one subject under a 6-minute VI schedule of food reinforcement. Punishment was added on the following day, and consisted of a shock of 50 volts (about 5 milliamperes) for 100 milliseconds following every response for the next 35 consecutive sessions. During successive days under punishment, responding gradually recovered over a period of 20 sessions. By the 22nd day under punishment, the number of responses per session can be seen to have stabilized, and no further increase occurred for the next 10 days. In this stable state, about 900 responses per day were made under punishment in contrast with the 2800 responses without punishment.

Variability of responding under this higher punishment intensity is slightly greater than seen under mild punishment, but this variability appears to be no greater than is normally encountered at lower response rates under variable-interval reinforcement.

A gradual acceleration of responding within each session, similar to that seen during the initial period of mild punishment, also exists under this moderate punishment. For at least the first 5 minutes of each session, responding was almost completely suppressed, with a gradual recovery of response rate during the next 15 minutes. The rate of responding during the latter 30 minutes of each hour was typically constant, with no further recovery. The dotted lines in Fig. 2 are drawn as a projection of the initial response rate. By comparing the slope of the actual response record with the slope of this dotted line, the degree of recovery of responding within each hour can be more readily ascertained. Although responding did recover considerably within each hour of punishment, the stable response rate at the end of the hour was still suppressed below the unpunished rate. Recovery is, therefore, incomplete.

Introduction of Severe Punishment

Recovery of responding did not typically occur under more intense punishment. Figure 3 presents an example of this stable suppression for one subject. During the unpunished 6-minute VI schedule of food reinforcement (top, Fig. 3), responding occurred at a uniform rate totalling about 4000 responses during the hour. Severe punishment was then added im-

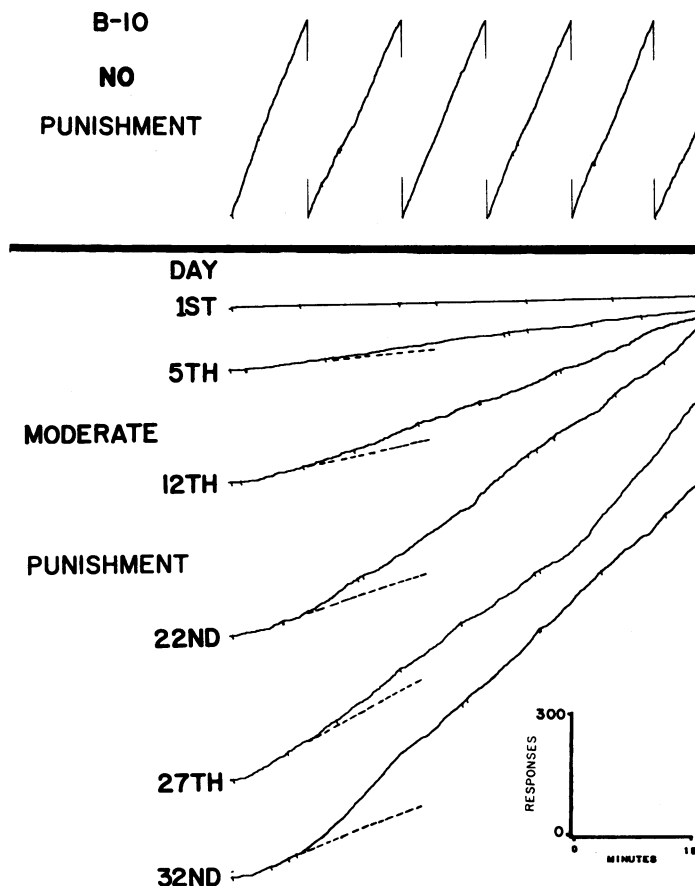


Figure 2. Partial recovery of responding during maintained moderate punishment. The top set of curves is the cumulative record of the responses prior to any punishment. Each of the lower curves is a complete daily record with the punishment following every response. A 6-minute, variable-interval schedule of food reinforcement is present on all days. The small oblique lines on the record indicate the delivery of food reinforcement. The dotted lines are a projection of the initial response rates, and indicate the degree of recovery by comparison with the angle described by the actual response records (solid lines).

mediately following each response at an intensity of 100 volts and a duration of 30 milliseconds during each of the following 21 sessions. The entire cumulative record of the responses for every other one of these 21 sessions under punishment is presented. It can be seen (bottom, Fig. 3) that the number of responses per session was immediately reduced to about 5% of its unpunished level. There is no increase or recovery of responding from session to session over these 21 days of punishment, in contrast with the marked recovery seen at the lower intensities. Under this severe punishment of approximately 10 milliamperes for 30 milliseconds, the responding remained suppressed.

Recovery of responding within each hour of severe punishment is very slight and is often absent on a given day or for most days for some subjects. As was also true at lower intensities, this more severe punishment produced no increase in the variability of the local rate of responding. Similarly, there is a fairly high degree of stability of the number of responses

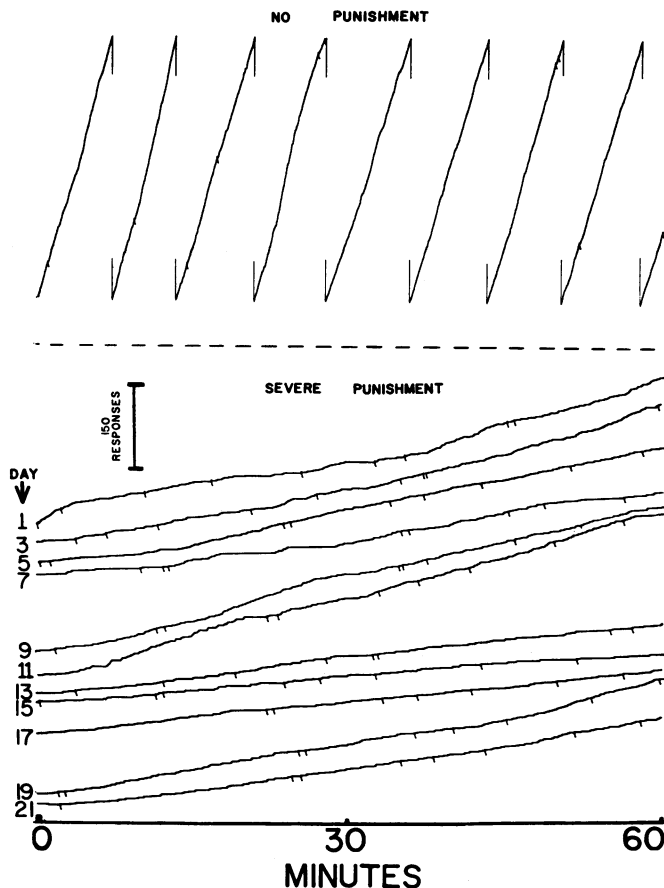


Figure 3. Minimal recovery of responding during maintained severe punishment. The top set of curves is the cumulative record of the responses prior to punishment. Each of the lower curves is a complete daily record with the severe punishment following every response. A 6-minute, variable-interval schedule of food reinforcement is present on all days. The short oblique lines on the record indicate the delivery of food reinforcement. No recovery of responding occurs from day to day, and only minimal recovery can be seen with any given day.

per day at this high intensity. In spite of the fact that the number of responses has been reduced to about one-twentieth of its unpunished level, the total range of the number of responses per day under this severe punishment varies between a minimum of 150 and a maximum of 300. The degree of stability found for number of responses per day is usually a reflection of the degree of acceleration of responding within the session. In Fig. 3 (severe punishment), little acceleration exists within each hour, and, consequently, little variation of the total number of responses results. By comparison, considerable acceleration was seen in Fig. 2 (moderate punishment), and, consequently, greater variation of the total number of responses resulted. The greater variability of responses per day seems to be determined by the time taken to reach a uniform rate on a given day, not by any large difference in this ultimate rate.

Introduction of Very Severe Punishment

The large degree of recovery from punishment seen above might indicate that punished behavior will recover or persist only if sufficient time is allowed. This conclusion does seem

to be warranted over a large range of intensities, but at extreme intensities a different picture emerges. When punishment is made extremely severe, responding can be completely eliminated, with no evidence of recovery. This complete suppression was found at intensities greater than 130 volts (about 15 milliamperes) delivered for durations greater than 100 milliseconds, or for intensities greater than 70 volts at longer durations (300 milliseconds). An example of this complete suppression can be seen from the cumulative-response records of one subject in Fig. 4. The reinforcement schedule is a 6-minute VI for food, and it produced the usual stable rate shown in the top section of Fig. 4. A very severe punishment was then delivered after every response during each of the following 20 sessions. This punishment produced immediate and virtually complete suppression with only 1 or 2 responses occurring during any of these sessions under punishment. Under such a low rate of responding during this variable-interval schedule of reinforcement, virtually every response resulted in a food reinforcement. Nevertheless, by the 13th session, suppression was complete and no

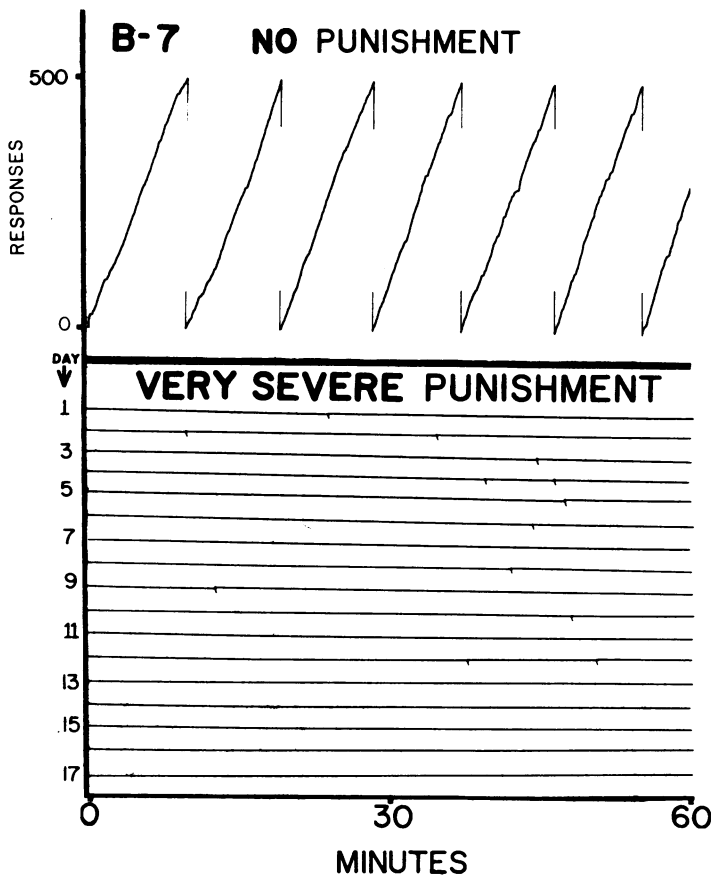


Figure 4. Immediate and complete suppression of responding during maintained punishment of very severe intensity. The top set of curves is the cumulative record of the responses prior to punishment. Each of the lower curves is a complete daily record with the very severe punishment following every response. A 6-minute, variable-interval schedule of food reinforcement is present on all days. The actual delivery of the food reinforcement is not indicated on the record for no punishment. Each downward pip of the lower records indicates the delivery of a reinforcement and, because of the nature of the variable-interval schedule, the occurrence of the punished responses which produced this reinforcement.

further instance of a response occurred. So complete was the suppression that for 12 days after the removal of punishment, no responses were made.

In summary, the effect of adding punishment to previously unpunished responses was found to be a sharp reduction in the frequency of those responses. If the punishment is at all effective, this reduction of responding occurs immediately and regardless of intensity. The intensity of punishment does play a crucial role in determining whether these responses will recover during continued punishment. At relatively "mild" intensities, the responding gradually and progressively increases in frequency until the stable rate under punishment is at least equal to the rate observed without punishment. In contrast to the complete recovery under mild punishment, under relatively "moderate" punishment the recovery of responding is only partial. The responding does recover day by day from the large suppression produced by the initial introduction of the moderate punishment; but, in this case the responses eventually stabilize at a level that is less than the unpunished level. At relatively "severe" intensities, little or no recovery of responding occurs during maintained punishment; the suppression induced by the initial addition of this severe punishment continues as long as the punishment is continued. At "very severe" intensities of punishment, responding is immediately and often completely suppressed. Comparable changes occurred within each hour of exposure. At mild and moderate intensities, responding is greatly reduced during the initial portion of each hour, with some recovery during the course of the hour. At severe intensities of punishment, this gradual recovery within each hour of exposure is occasionally absent.

Removal of Punishment

When punishment was discontinued, it was found that the responses increased in frequency, but this increase in frequency was usually not simply a return to the unpunished level. Instead, the responding often "overshoots" or "compensates," giving rise to a level of responding that exceeds the usual unpunished level. The course of these changes can be followed in Fig. 5 for one subject when a long period of severe punishment (90 volts) was discontinued for 20 sessions. The immediate effect of discontinuing the punishment (arrow) was a sharp increase in the number of responses on the first day without punishment. During the following days without punishment, the responding returned to the lower level appropriate to the schedule of food reinforcement. The cumulative records for this same subject (bottom, Fig. 5) show in greater detail the changes during this compensatory increase in responding. During the first day without punishment, recovery from the effects of the previous punishment sessions was evident from the very beginning of the first hour, giving rise to a rate of about 3 responses per second. This high rate decreased gradually throughout this first day to a rate of approximately 1.5 responses per second by the end of the hour. During the 10th daily session without punishment, the rate returned to its usual unpunished level of approximately 1.5 responses per second with no progressive change in rate throughout the hour.

This temporary increase of responding following the removal of punishment was also found after moderate intensities of punishment. The top section of Fig. 6 presents the total number of responses per day for one subject during and following 20 days of moderate punishment. During the sessions under punishment, a shock of 50 volts at a duration of 30 milliseconds was delivered after every response. It can be seen that there is an increase in the number of responses during the first day without punishment, but on subsequent days the number of responses returned to a lower level. As was also true in the previous example

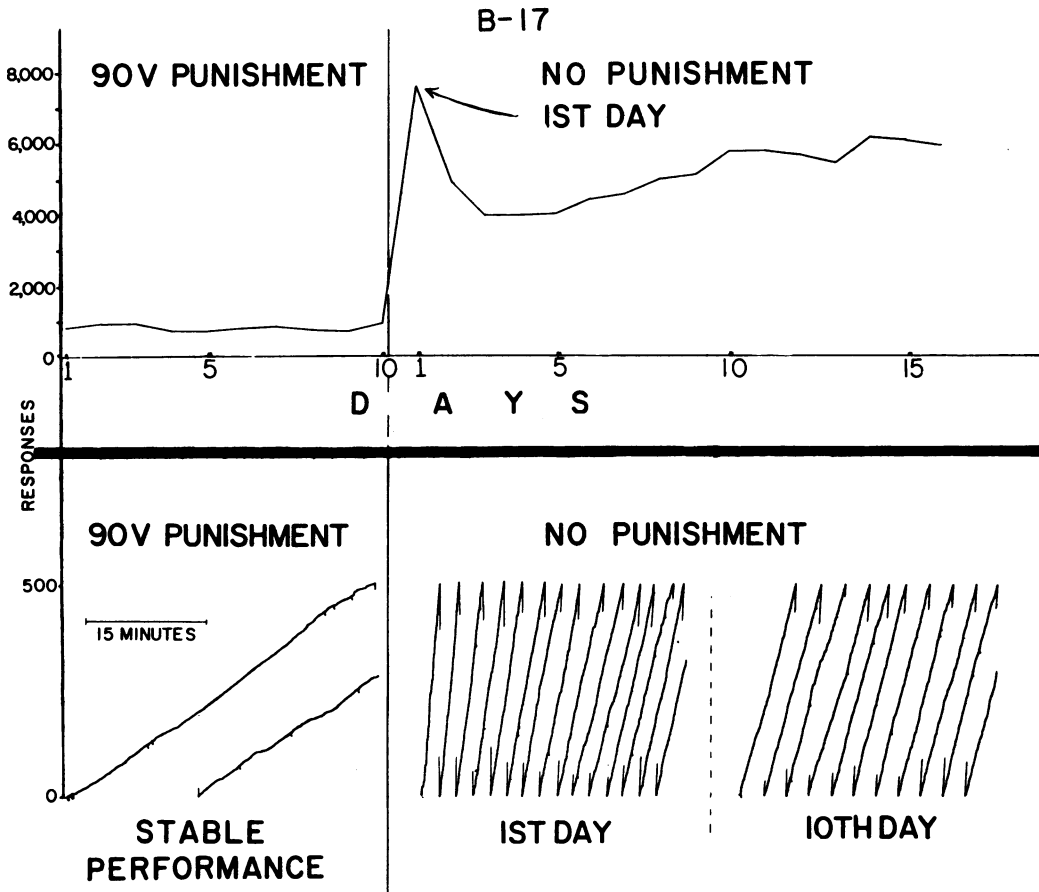


Figure 5. Compensatory increase of responding following the removal of severe punishment. The top section shows the change in the number of responses per day. The bottom section shows the same changes in greater detail via the cumulative-response records.

(Fig. 5), this increase of responding on the first day without punishment is not attributable to a general increase in rate throughout that day, but is restricted to the first part of this first day without punishment. During the remainder of this session, and on subsequent sessions (see Day 10), the responding returned to the level normally seen for this subject in the absence of punishment. This compensatory increase is not only found after the removal of moderate and severe punishment, but has also been found (Azrin, 1959b) following the removal of a mild, and ultimately ineffective, punishment intensity. Gradual recovery following the removal of punishment has been found only when the punishment was intense enough to produce complete suppression (Fig. 4).

When punishment was discontinued in the above examples, the responses showed a sharp increase in frequency. The rapidity of this change can be observed more clearly within a single session, as in Fig. 7, when the punishment was discontinued and then reinstated. Within a few seconds after the termination of the punishment (first arrow), responding immediately increased in rate. When this same intensity of punishment was reinstated (second

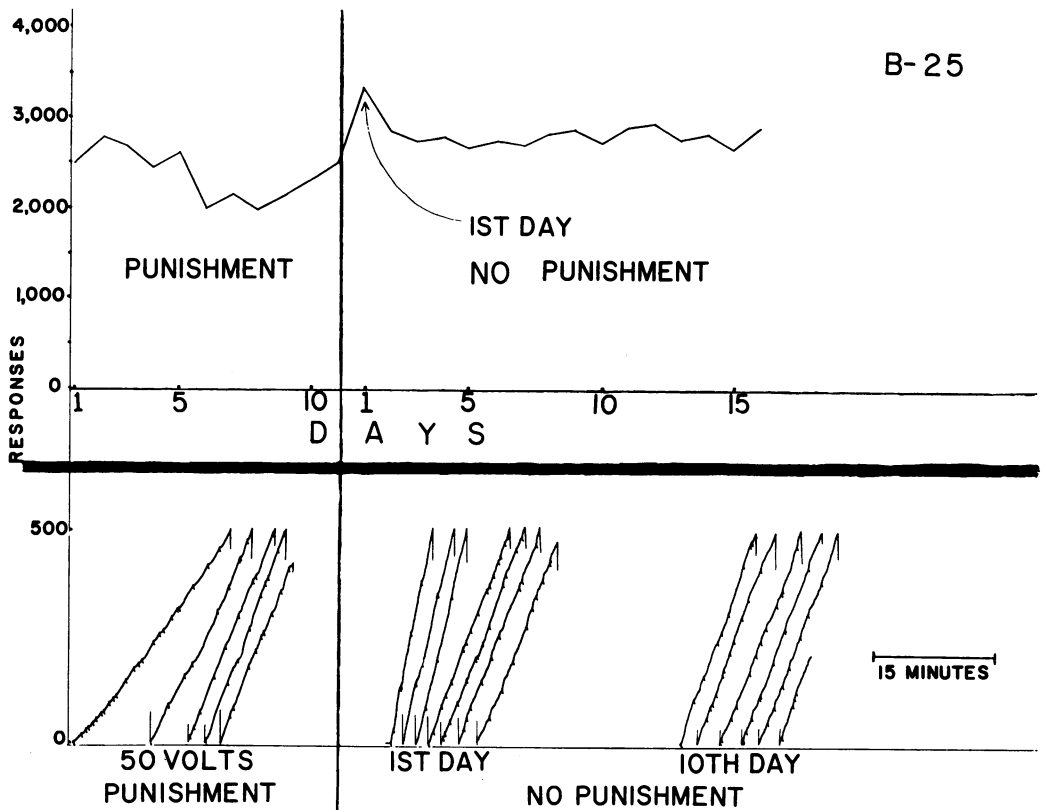


Figure 6. Compensatory increase of responding following the removal of a moderate punishment. The top section shows the change in the number of responses per day. The cumulative records in the bottom section show the changes in response rate within each session consisting of positive acceleration under punishment and a negative acceleration upon the removal of punishment. The delivery of food reinforcement is indicated by the short, oblique pips on the cumulative record.

arrow), equally rapid suppression resulted, but the degree of suppression (dotted line) is initially greater than that seen before the punishment was discontinued. The effect of temporarily discontinuing punishment might well have been expected to produce an increase in subsequently punished responses. Instead, the interjection of this period of no punishment produces a decrease. This period of marked suppression upon the reintroduction of punishment is followed by a recovery of responding within a few minutes, and strongly resembles the recovery process seen at the beginning of this session (dotted line).

In summary, elimination of a period of punishment does not produce a return to the unpunished level of responding. Typically, there is a period of "overshooting," in which the responding after punishment temporarily increases to a level exceeding the usual unpunished level.

Increases in Punishment Intensity

Consider now the situation in which each response has been punished over an extended period of time, whereupon the punishment intensity is abruptly increased. The typical effects of increasing the punishment intensity is seen in Fig. 8, which shows the changes in respond-

ing following several such increases for one subject. The changes were: (a) from no punishment to 10 volts; (b) from 10 volts to 20 volts; (c) from 20 volts to 30 volts; and (d) from 30 volts to 40 volts. On the first day under 10-volt punishment, immediate suppression (at *A*) results with complete recovery after 30 minutes. This large suppression upon the initial addition of punishment has also been seen in Fig. 1. On the 2nd day, the suppression is limited to the first 10 minutes (see *B*); on the 3rd day, to the first 2 minutes (at *C*); and by the 4th day, no suppression under 10 volts can be detected (at *C'*). The punishment was then increased from 10 volts to 20 volts. On the first day of 20 volts, a substantial reduction of responses is produced at the beginning of the session (at *D*); but the response rate at the end of this first hour under 20 volts is only slightly less than that seen in the preceding hour under 10 volts. By the 15th hour under 20 volts there is less reduction of responding, and even this is largely localized to the first 20 minutes (at *E*) of the hour. By the 35th session under 20 volts, this suppression during the initial part of the hour has been further re-

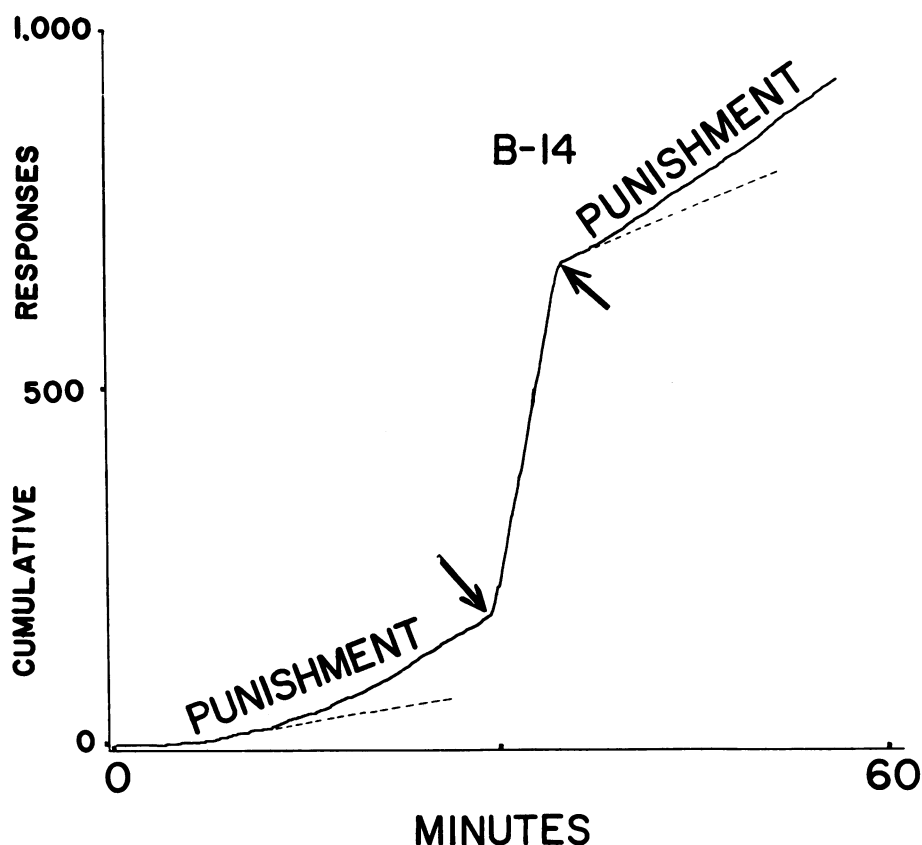


Figure 7. Effect of a brief period without punishment. The responses are being reinforced throughout by a 1-minute, variable-interval schedule of food reinforcement. The actual delivery of these reinforcements is not indicated. The lower arrow marks the moment at which the punishment was discontinued, and the upper arrow marks the moment at which the punishment was reinstated. The dotted lines are a projection of the response rates at the start of the session and at the start of the reinstated punishment period. During the period of punishment, the brief punishing stimulus was delivered following every response.

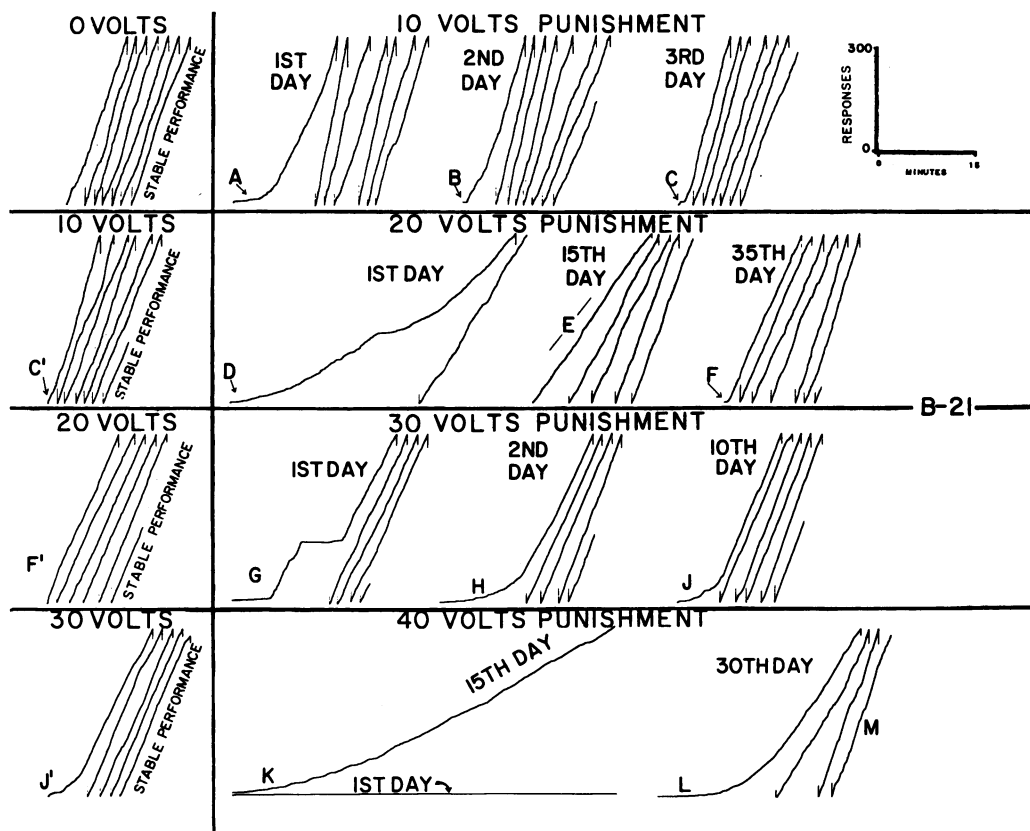


Figure 8. Suppression and recovery following abrupt increases in the existing intensity of punishment. Reinforcement is being delivered throughout according to a 1-minute, variable-interval schedule, but is not indicated on the records. The cumulative-response records within each row show the initial suppression and subsequent recovery of responses following a 10-volt increase in punishment intensity. The letter designations (A-L) refer to the marked period of suppression at the start of each day (see text). At each of the intensities indicated, the punishment is being delivered following every response.

stricted to the first minute or so (at *F*), and the total number of responses is comparable with that seen under the lower (10 volts) punishment intensity. After 5 additional sessions (at *F'*), the 40th under 20 volts, not even the initial part of the session reveals any suppression. At this point, the punishment intensity was increased from 20 volts to 30 volts. Again, the result is a large degree of suppression (at *G*) during the initial part of the first session under this higher intensity, with subsequent recovery during the latter part of the same session. On the 2nd day, the suppression is localized to the first 15 minutes (at *H*), by the 10th session to the first 10 minutes (at *J*), and by the 15th session to the first 5 minutes (at *J'*). In every case, recovery is complete by the end of the hour. The intensity was then increased once more from 30 volts to 40 volts with the same cycle of suppression (at *K* and *L*) and recovery (at *M*).

In order to obtain a clearer view of the response changes produced at the moment of increasing the intensity of punishment, several probes were conducted in which the intensity was increased during a single session. With these probes the session duration was often in-

creased to provide uninterrupted observation of the recovery process. The typical results obtained can be seen from Fig. 9, which constitutes the response record for a 6-hour session. After the first hour, the punishment intensity was abruptly changed (at dotted line) from 20 volts to 60 volts, with no interruption of the session or other change in stimulation. This increase of punishment produced an immediate decrease in response rate from 60 per minute to about 4 per minute. This lower rate prevailed for approximately an hour, after which responding steadily increased. During the last hour, the response rate was greater than 15 responses per minute, having more than tripled since the initial increase in the punishment intensity.

Increasing the punishment intensity seems to have the same general effect as the initial addition of punishment. In both instances, the new punishment intensity produces a large suppression at the moment of changeover, with substantial recovery after continued exposure to this new intensity. Only at severe intensities of punishment has further increase failed to produce an abrupt decrease in responding. The data concerning this are not yet definitive, however.

Decrease of Punishment Intensity

When an existing intensity of punishment was decreased, it was found that the response rate eventually reflected this reduced intensity by an increase in responses. The speed of this adjustment in rate seems to be critically dependent upon the degree of change of the punishment intensity, but in no case has the rate adjusted immediately. Figure 10 shows an example of a relatively rapid adjustment, wherein the total number of responses per session can be seen to increase on the very first day that the reduced punishment was in effect. Not until the 2nd day, however, did the responding reach the level that seems appropriate to this reduced intensity. Nevertheless, this increase in responding following the reduction of pun-

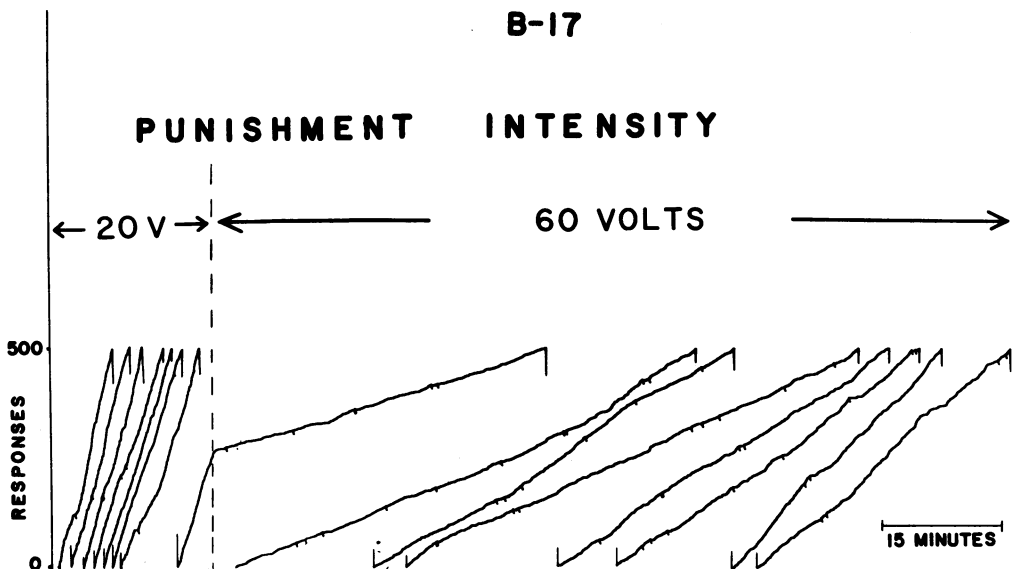


Figure 9. Suppression and recovery of responding within a single day following an abrupt increase of the existing level of punishment. Reinforcement is indicated by the short oblique marks on the cumulative-response record.

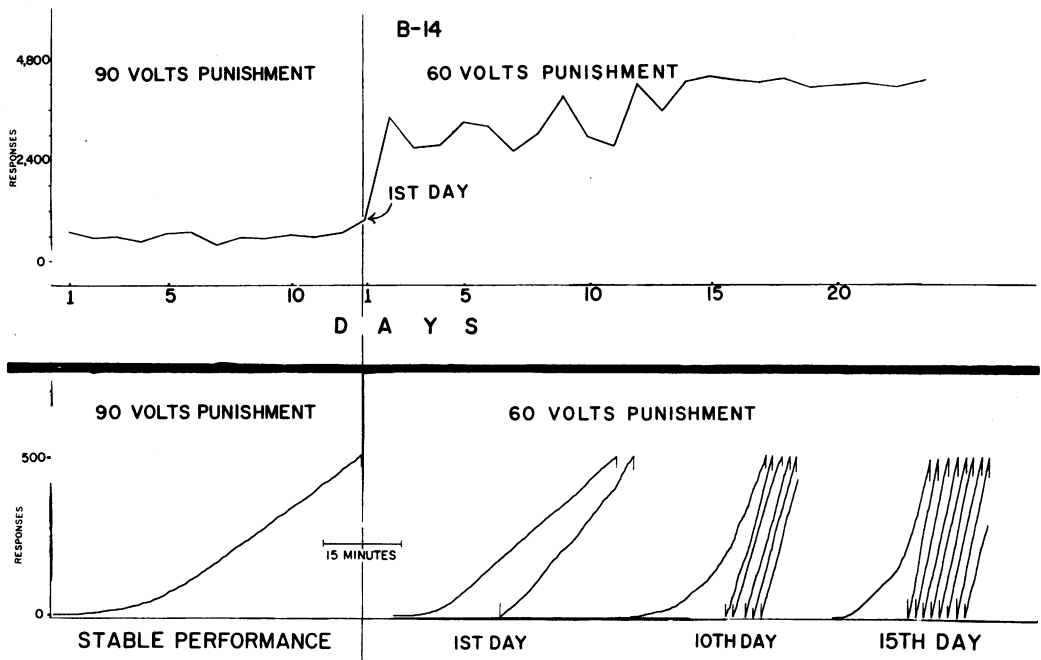


Figure 10. Gradual increase of responding following a decrease of the existing intensity of punishment. Top section presents the change of the number of responses per day. Bottom section presents cumulative-response records for illustrative days for the same subject. The delivery of food reinforcement is not indicated.

ishment was unusually rapid. The more typical course of events is described in Fig. 11, where the reduction of punishment from 90 volts to 80 volts produced no increase in responding until the 6th day. The level of responding did not reach a stable value until 17 days of continued exposure to this reduced punishment. At that time, the adjustment to the reduced intensity resulted in a doubling of the responding.

This gradual adjustment of responding to a lowered punishment intensity is in marked contrast with the rapid adjustment of responding found when the punishment is increased. As might be expected, the speed with which the response rate adjusts to a lowered intensity depends greatly on the degree to which the punishment is lowered. So, for example, the reduction of punishment from 90 volts to 80 volts required from 5 to 10 days to affect responding (Fig. 11), whereas the reduction from 90 volts to 60 volts required only 2 days (Fig. 10). Not unless the punishment is reduced to a zero or near-zero intensity (Fig. 5-7) does the punished behavior adjust immediately to the reduction of punishment.

Stable State Under Punishment

The notion of a stable state of punished behavior is often difficult to accept, especially when one observes the number of responses gradually increasing or decreasing from day to day over a period of 20 days. Certainly, the usual practice of observing only the first few minutes or hours of punishment would seem to preclude observation of some of the most important aspects of the punishment process. Even after 20 consecutive days at a given intensity of punishment, the possibility of further recovery of responding should not be excluded. Consequently, a given intensity of punishment was usually maintained for a min-

imum of 10 days of stable performance whenever some notion of the stable effect of that intensity was desired. Under this criterion of stability, as many as 60 days were required before critical judgment could accept the observed pattern or frequency of responses as being stable. With these limitations in mind, it is possible to compare the "stable performance" at several intensities of punishment for two subjects (Fig. 12). It can be seen that the more intense punishment produces a greater reduction of responding. Also, there is an increase of the response rate throughout each session at the lower intensities, but a more uniform rate at the higher intensities. No curve for intensities less than 60 volts was included since the stable performance at these lower intensities often revealed no reduction of responding. (See Fig. 1.) Certainly, the degree of suppression shown in Fig. 12 would be quite different if shorter periods of exposure to punishment had been used.

Changes in Food Deprivation

The subjects in this study were maintained at a fixed body weight by feeding immediately after each experimental session. The amount of food given to the subject was equal to the difference in the weight of the subject after each session as compared with his predetermined "running weight." This commonly used procedure (Ferster & Skinner, 1957) was found to

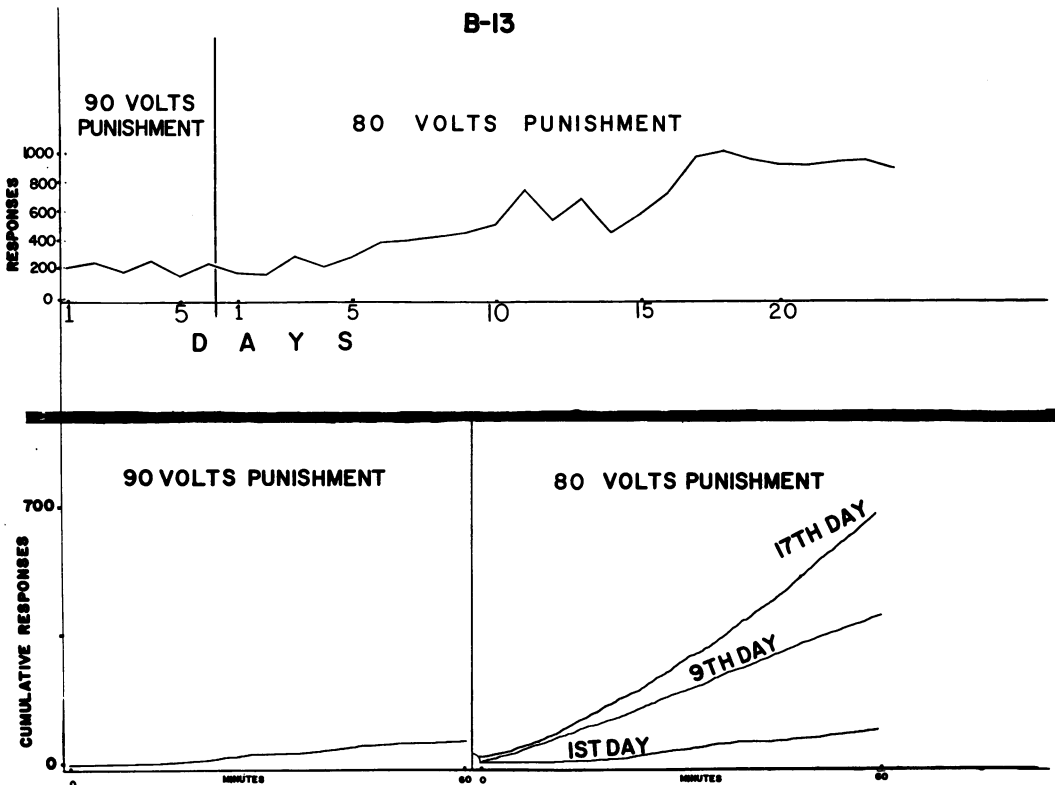


Figure 11. Extremely gradual increase of responding following a slight decrease of the existing intensity of punishment. Top section presents the change in the number of responses per day. The bottom section presents cumulative-response records for illustrative days for the same subject. The delivery of food reinforcement is not indicated.

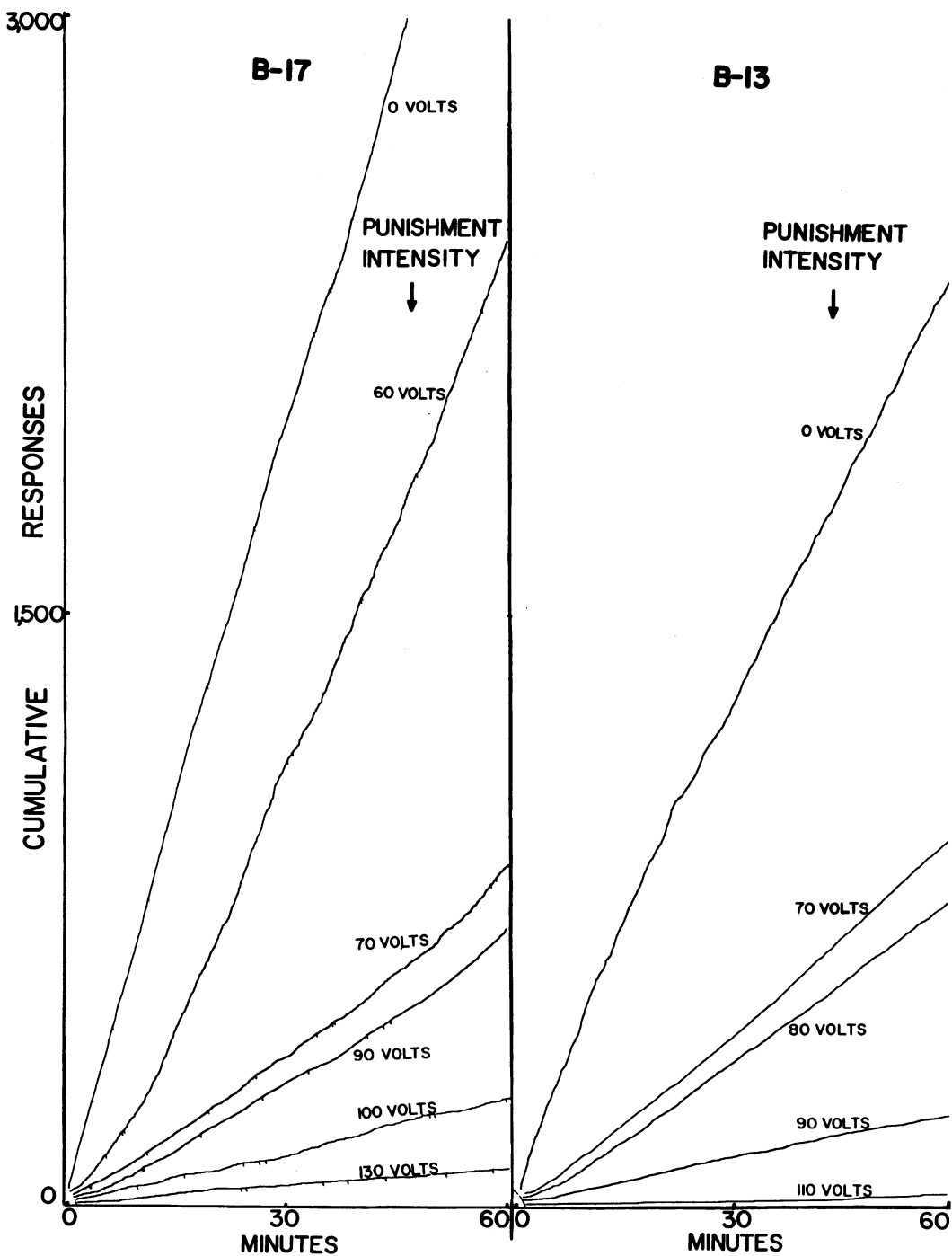


Figure 12. Response rate as a function of punishment intensity for two subjects. Each curve is the cumulative-response record for a 1-hour period of concurrent food reinforcement and punishment. The delivery of food reinforcement is indicated for Bird 17 by short oblique lines, but is not indicated on the record for Bird 13.

be adequate in maintaining body weight between a 20-gram range of variability, and resulted in very slight changes in the food-reinforced response rate prior to punishment. When punishment was added, however, the same minor fluctuation in body weight frequently produced large variations in the response rate. An example of this sensitivity to deprivation level can be seen in the left section of Fig. 13, which shows the effect upon moderately punished responses of a change of only 20 grams in body weight. At 360 grams the acceleration in responding during the session not only was more gradual than at 350 grams, but the stable rate at the end of the hour was also reduced. At 370 grams the responding is reduced to a near-zero level, as compared with the 1300 responses observed at the slightly lower weight. The right section of Fig. 13 shows the effect of changes in body weight upon the uniform rate associated with more severe punishment. Here, the changes in body weight produce a simple change in the rates of response, with little or no acceleration of responding evident at any of the three deprivation levels. The number of responses is roughly tripled by a drop of only 30 grams of body weight. Because of these large effects of small changes in deprivation level, the procedure for controlling body weight was modified by establishing a

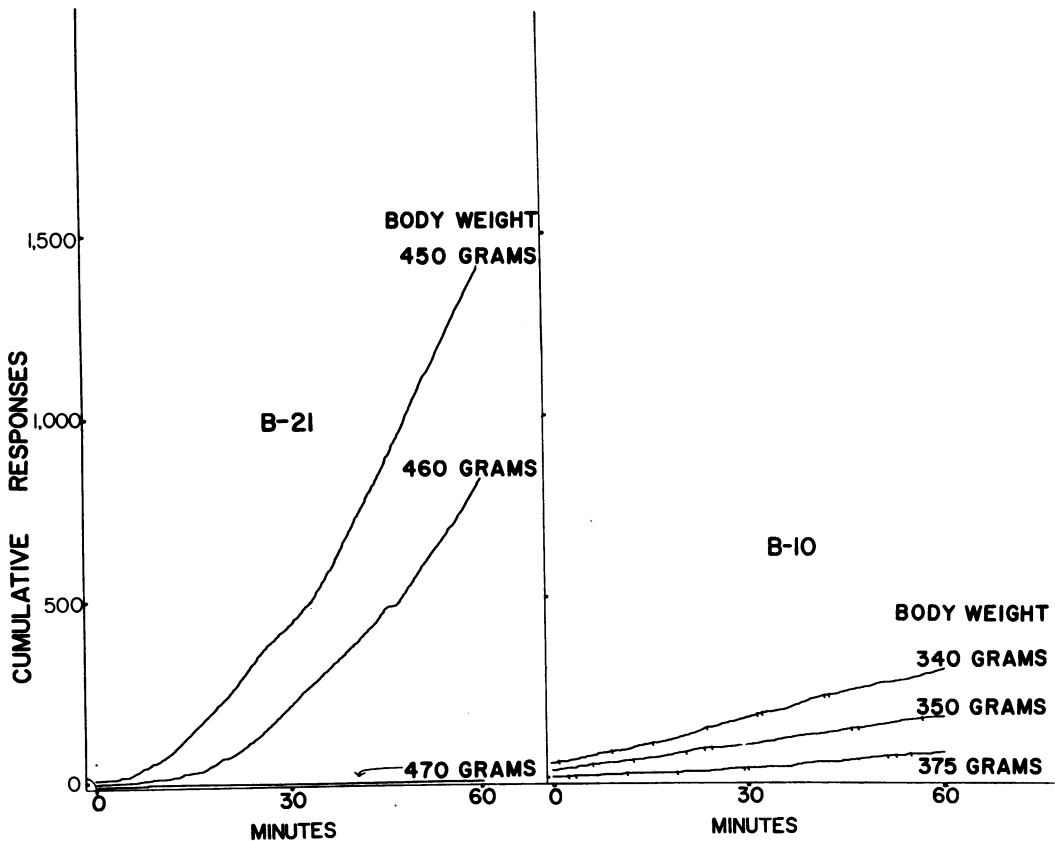


Figure 13. Effect of food deprivation on responses that are concurrently punished and food-reinforced. The left section constitutes a moderate punishment, and the right section, a severe punishment. The delivery of food reinforcement is indicated by short oblique marks on the record for Bird 10, but is not indicated on the record for Bird 21.

minimum and maximum quantity of food to be given after each session. Cyclic changes in weight were thereby minimized to a point where no significant effect on response rate could be detected.

Changes in food deprivation as a function of punishment were rare. Under the variable-interval schedule of reinforcement used in this study, only a very low trickle of responses was necessary to produce the full number of reinforcements scheduled during each session. Except at very severe punishment intensities that produced complete suppression, the number of reinforcements actually received during periods of punishment was the same as that received during periods without punishment. Since the body weight at the start of each session was held constant in the manner described above, the progressive increase of responding observed within punishment periods cannot be ascribed to changes in food deprivation.

The dramatic recovery of responding found during maintained punishment is not completely understood. Initial introduction into a stimulus situation associated with punishment does seem to be a dominant consideration in initiating a cycle of suppression and recovery. Some lines of evidence for this interpretation are the large initial suppression and subsequent recovery found (1) at the initial introduction of punishment, (2) upon the abrupt increase in punishment intensity, (3) at the beginning of each session under punishment, and (4) after a brief period of no punishment. One other relevant fact is the effect of a "rest-period" or time-out period during the punishment process, an example of which is shown in Fig. 14. In the middle of a session under punishment, all illumination in the experimental chamber was removed for 20 minutes, thereby preventing the subject from responding. When the illumination was restored, responding did not continue at the same level prevailing prior to this time-out period. Instead, a few minutes of almost complete suppression resulted before the rate of responding returned to its previous value. These changes are in accordance with the previous findings of heightened suppression during the initial transition into a situation associated with punishment. This characteristic reduction of responding following a time-out period does not occur in the absence of punishment (Ferster & Skinner, 1957).

This recovery from the initial introduction to punishment seems to be a general phenomenon. In the present study the recovery process was observed under various (1) intensities of punishment, (2) levels of food deprivation, and (3) frequencies of reinforcement. The same phenomenon has been observed in other investigations when electrified grids were used to deliver either unavoidable shock (Ferster & Skinner, 1957; Azrin, 1956) or conventional punishment. The recovery process has also been noted (Skinner, 1938) with: a different aversive stimulus, a slap; a different species, rats; as well as a different schedule of food reinforcement, fixed-ratio (Azrin, 1959b). Since the recovery process seems to exist under a wide range of conditions, it is somewhat surprising that other extensive studies of punishment (Estes, 1944; Dinsmoor, 1952; Azrin, 1958) have not reported this relation. The results of this investigation suggest several factors that may have contributed: (1) insufficient duration of exposure to the punishment condition; (2) averaging of data within and between subjects; and (3) the use of a very severe intensity of punishment.

The orderliness of the response rates observed under punishment was somewhat surprising with respect to initial expectations concerning the disruptive effects of punishment. Yet, it was found that the addition of punishment, regardless of intensity, did not produce more variability of the response patterns than had existed prior to punishment. The absence of such variability may be related to the relative constancy of punishment intensity made

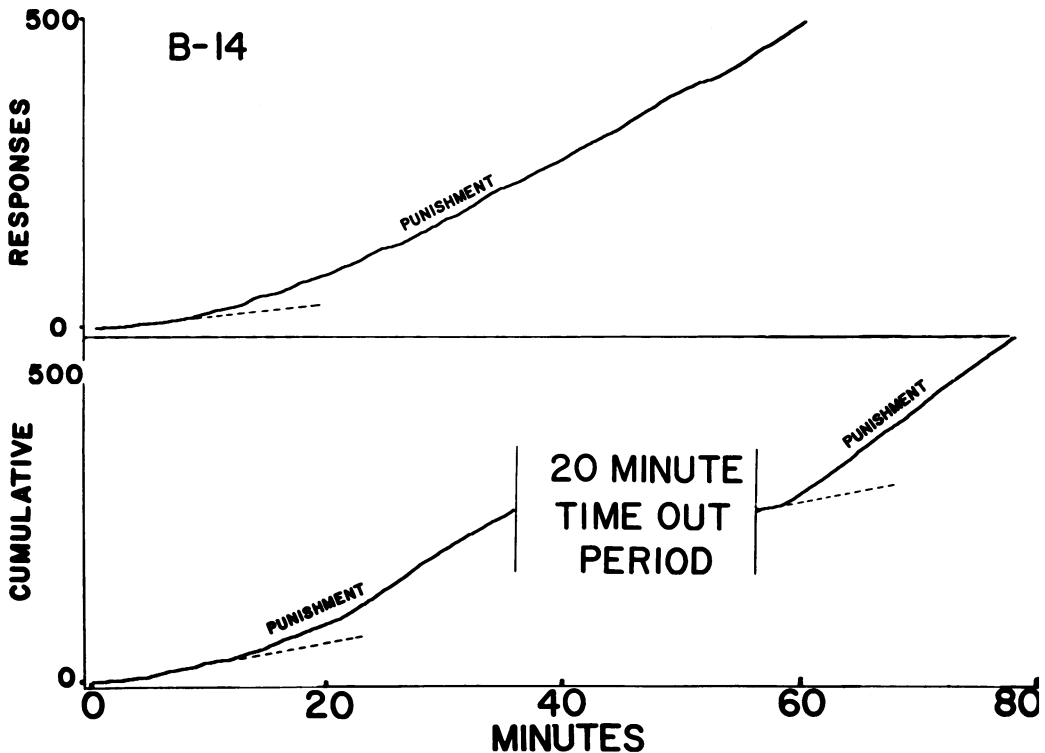


Figure 14. Effect of a time-out period upon punished responses. The dotted lines are a projection of the rate of responding at the beginning of the session (on left) and shortly after the end of the time-out period. Top section presents the response record for the same subject when no time-out period is introduced. The deliveries of the food reinforcements are not indicated.

possible by implanted electrodes. On the other hand, in a prior study which also used implanted electrodes, punishment did disrupt the more complex temporal pattern of responding associated with fixed-ratio reinforcement (Azrin, 1959b); but such disruption was restricted to the initial stages of the punishment period. It may be, therefore, that this increase in the variability of responding is primarily a consequence of changing stimulus conditions, and not a stable characteristic of the punishment process.

A comparison of the present finding with those of previous studies indicates that the nature of the underlying reinforcement schedule is important in determining the effects of punishment on the temporal pattern of responding. The present findings showed that punishment produces a general depression of the uniform rate of response associated with variable-interval reinforcement. In contrast, previous findings (Azrin, 1958) showed that punishment of fixed-interval responses produced a lengthening of the pausing following reinforcement, with relatively little change in the high terminal response rate preceding each reinforcement. Similarly, punishment of fixed-ratio responding has been found (Azrin, 1959b) to produce a lengthening of the usual pauses after each reinforcement, with little change of the response rate once the responding began. In both the fixed-ratio and fixed-interval schedules, punishment produced an increase of existing pauses with little change of the higher response rates.

SUMMARY

Punishment in the form of electric shock was delivered through implanted electrodes following every response during a variable-interval schedule of food reinforcement. The initial addition of punishment was found to produce a disproportionately large suppression of responding with subsequent recovery, often complete, while the punishment was being maintained. This recovery from punishment occurred within each daily period as well as from day to day over periods as long as 60 days. At very intense punishment intensities, this recovery process was usually reduced or absent. The same cycle of immediate suppression and gradual recovery is produced by abrupt increases of an existing level of punishment. Conversely, when an existing level of punishment is decreased, responding adjusted gradually to a new and higher level. When the punishment is reduced to zero, however, the previously punished responses briefly "overshoot," reaching a higher rate than is usual for the unpunished level. No increase in the variability of the local response rate results from the punishment of responses under variable-interval food reinforcement. Under this simultaneous food and punishment schedule, responding continues to occur at a fairly uniform rate, which is directly related to the degree of food deprivation and inversely related to the punishment intensity. Interruption of the punishment process, either by a period of no punishment, or by a complete time-out period, produces renewed suppression upon the reinstatement of the punishment.

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